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MEMORANDUM

TO: Tom Moe, U. S. Steel
FROM: Mike Johnson/Mat Knutson, Liesch Associates
DATE: January 26, 2010
RE: January 2010 Minntac Tailings Basin Seep Estimate

The following memo has been prepared to document the methods used to develop an estimated seepage rate from the Minntac Tailings Basin. The information in this memo is based upon information shared during a January 22, 2010 conference call between U. S. Steel (USS), Hatch, CRA, Barr, and Liesch.

The seep rate through the dikes was calculated by both Liesch and Barr using similar but slightly different methods.

Liesch utilized chloride as a tie element and downstream flow information to back-calculate an estimated seep flow rate. Chloride concentrations were measured at Seep 030 and Seep 020. During a corresponding period, chloride concentrations and flow rates were measured downstream at location 701 on the Sandy River and location D-1 on the Dark River. Data used for the calculation was collected in 2003, 2007, and 2009 (the 2009 data was incorporated following the Jan 22, 2010 conference call). It was assumed all chloride observed at the downstream locations originated from the tailings basin. Based on this information, an average seepage flow rate of 2,896 gpm was estimated.

Barr conducted a slightly more complex yet similar analysis utilizing sulfur as the tie element. See attached Barr memorandum for greater detail on the methodology used by Barr. The Barr estimated seep flow rate was 3,049 gpm.

CRA was requested by USS to estimate the loss of water from the tailings basin into the groundwater through the bottom of the tailings basin. CRA reported that their estimate from the clear pool area (cell 1 and cell 2) ranged from 6 to 154 gpm with a mean of 43 gpm. This estimate was based on 25, 000 linear feet of wetted perimeter on the east side of Cell 1 and the north/east side of Cell 2. See attached CRA memorandum for greater detail on the methodology used by CRA. It was acknowledged on the conference call that the CRA value did not represent all the water potentially leaving the tailings basin bottom. Due to the fairly small estimated rate (compared to the estimated seep flow rates), the mean average was effectively doubled and rounded up to 100 gpm to represent a reasonable estimate of total tailings basin loss to the groundwater.

It was agreed during the conference call that the Liesch and Barr methods would be averaged with the rounded-up CRA groundwater seep estimate then added to that result. **This results in a total estimated seep flow rate from the tailings basin of 3,070 gpm.** USS has indicated that this value should be used in future modeling of the tailings basin for treatment system sizing.

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Table A18.2. Wild rice resources in the Sand-Pike River.

DEPARTMENT: Natural Resources - Enforcement

DATE : December 7,1987

TO : Amy Loiselle

FROM : Gerald McHugh, Wild Rice Coordinator

SUBJECT : Water Discharge Minntac Tailings Pond

The Wild Rice Beds involved in the discharge down the Sandy River are Sandy and Little Sandy Lakes which in a good year will have about 200 acres of rice. These lakes are about a mile down stream from discharge and seepage sites. There is also a 40 to 50 acre bed further down the river that is a wide spot in the Sandy River.

These beds produce a good quality rice and generally follow the trend of the region as far as quainty of rice in any given year. I found as many of the old arial surveys as I could in the files in St. Paul. They go back as far as 1966.

Year	Twin Lakes	Statewide
1966	Fair	Fair to Good
1968	Fair	Fair
1970	Good	Good
1972	Good	Good
1973	Fair	Good
1977	Poor	Good
1978	Poor	Poor
1980	Fair	Good

Table A18.2. Wild rice resources in the Sand-Pike River.

1981	Fair	[illegible]
1982	[illegible]	[illegible]
1984	Poor	Good
1985	Poor	Poor
1986	Poor	Poor
1987	Poor	Good

The bed on the river was not included in the areial survey but was in the surveys I did since 1984. There was good rice in in 1984, 1985 and 1987. The rice was poor in 1986.

These above mentioned rice beds are important not only for the rice that is harvested but also as waterfowl hunting areas which are in relatively short supply in the area. The waterfowl hunting potential is especially good for the Sandy Lakes. A good rice crop on these lakes will attract water fowl which are on the nearby tailings pond. The tailings pond are not hunted and hold several thousand waterfowl in the fall.

The discharge presents two hazards to the above mentioned wild rice beds. First and foremost is the chemical composition of the discharge water. The Sulphate ion concentration of the water in a series of tests exceeded 200 ppm. and up to over 700 ppm. Wild rice is relatively intolerant of sulphates and no large beds are found in waters with concentrations of over 10 to 20 ppm. sulphate ion conc. Secondly the increased volume of water will exacerbate a already serious problem of high water in the Sandy Lakes.

Table A18.2. Wild rice resources in the Sand-Pike River.

The Division of Enforcement is charged with management of wild rice in the public waters of the State of Minnesota. Therefore it is my recommendation that the Division of Environment vigorously oppose the granting of a permit to discharge tailings water into the Sandy River.

Gerald McHugh

Gerald S. McHugh

Wild Rice Coordinator

Sandy Lake and Little Sandy Lake Monitoring (2010-2016)

Prepared by:
Darren J. Vogt
Environmental Director

Technical Report 16-06
December 2016

1854 Treaty Authority
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Sandy Lake and Little Sandy Lake Monitoring (2010-2016)

Introduction

Under an agreement between the Bois Forte Band of Chippewa and the United States Steel Corporation-Minnesota Ore Operations, a monitoring program was completed in 2010-2014 at Sandy Lake and Little Sandy Lake. The United States Steel Corporation provided funding support for monitoring activities during these years. The 1854 Treaty Authority, in support of the Bois Forte Band and at their request, completed the monitoring work. Although the agreement was not extended into 2015-2016, the 1854 Treaty Authority continued the program.

Sandy Lake and Little Sandy Lake, also known locally as the Twin Lakes, historically have produced good stands of wild rice. Wild rice harvesters utilized the lakes when suitable crops were present. A lake survey in 1966 indicated moderately dense to dense stands covering both lakes. Rice production generally declined through the 1970s and 1980s, with little or no rice found in the lakes during a 1987 survey. Rice production has since remained poor. The lakes are located downstream of the tailings basin at the U.S. Steel Minntac iron ore operation. Construction of the tailings basin began in 1966. The resulting changes to water quantity and/or water quality in the system may have impacted wild rice in the Twin Lakes. Construction of a seepage collection system completed in late 2010 and other possible actions at the tailings basin may change the conditions in the Twin Lakes. With that in mind, monitoring activities were completed in 2010-2016 to document conditions in the lakes.

Monitoring activities completed in 2010-2016 have included:

- water depth recording
- inlet and outlet field surveys
- water sampling
- vegetation surveys
- aerial surveys

This report summarizes results from monitoring activities from all six years. Separate reports contain similar information from monitoring activities completed those years:

- *Sandy Lake and Little Sandy Lake Monitoring 2010,* Technical Report 10-07, December 2010
- *Sandy Lake and Little Sandy Lake Monitoring 2010-2011,* Technical Report 11-07, December 2011
- *Sandy Lake and Little Sandy Lake Monitoring 2010-2012,* Technical Report 12-05, December 2012
- *Sandy Lake and Little Sandy Lake Monitoring 2010-2013,* Technical Report 13-06, December 2013
- *Sandy Lake and Little Sandy Lake Monitoring 2010-2014,* Technical Report 14-07, December 2014
- *Sandy Lake and Little Sandy Lake Monitoring 2010-2015,* Technical Report 15-07, December 2015

General Information

Sandy Lake (MN Department of Natural Resources # 69-0730) and Little Sandy Lake (MN Department of Natural Resources # 69-0729) are located north of Virginia, Minnesota in Township 59N, Range 18W, Sections 2, 3, 10, 11. Sandy Lake has a surface area of 121 acres, and Little Sandy Lake has a surface area of 89 acres. Please see Figures 1-3 for maps and an aerial photograph of the lakes.

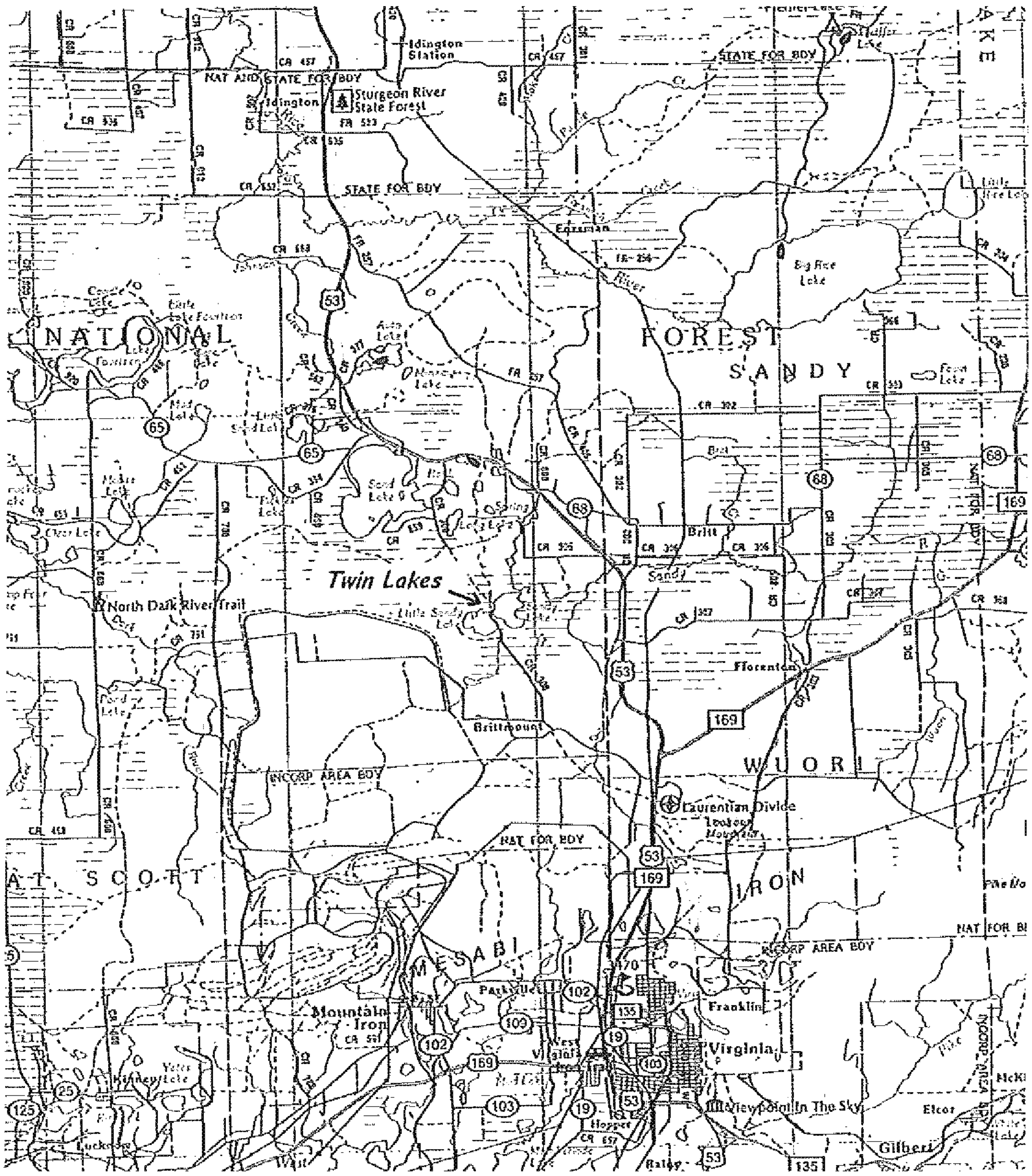

Figure 1: Sandy Lake and Little Sandy Lake (general vicinity and location)
Minnesota Atlas and Gazetteer, DeLorme, 1994

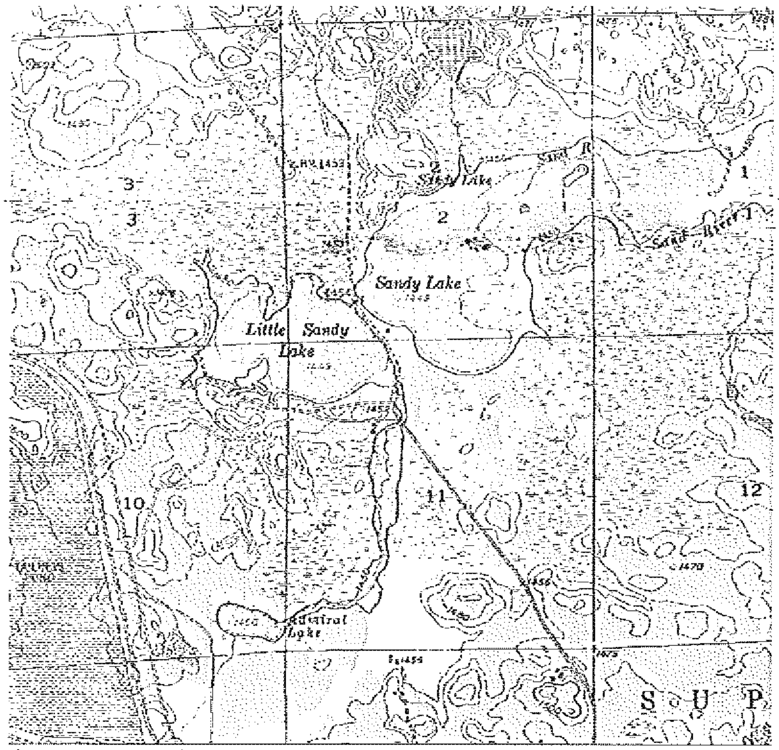

Figure 2: Sandy Lake and Little Sandy Lake (topographic map)
U.S. Geological Survey and Minnesota DNR


Figure 3: Sandy Lake and Little Sandy Lake (2003 aerial photograph)
U.S. Department of Agriculture, Farm Services Agency, Aerial Photography Field Office

Most of the land around the lakes is in federal ownership and managed by the U.S. Forest Service, Superior National Forest. Some parcels of private ownership are located on the northeast shoreline of Sandy Lake and surrounding the outlet. Please see Figure 4.

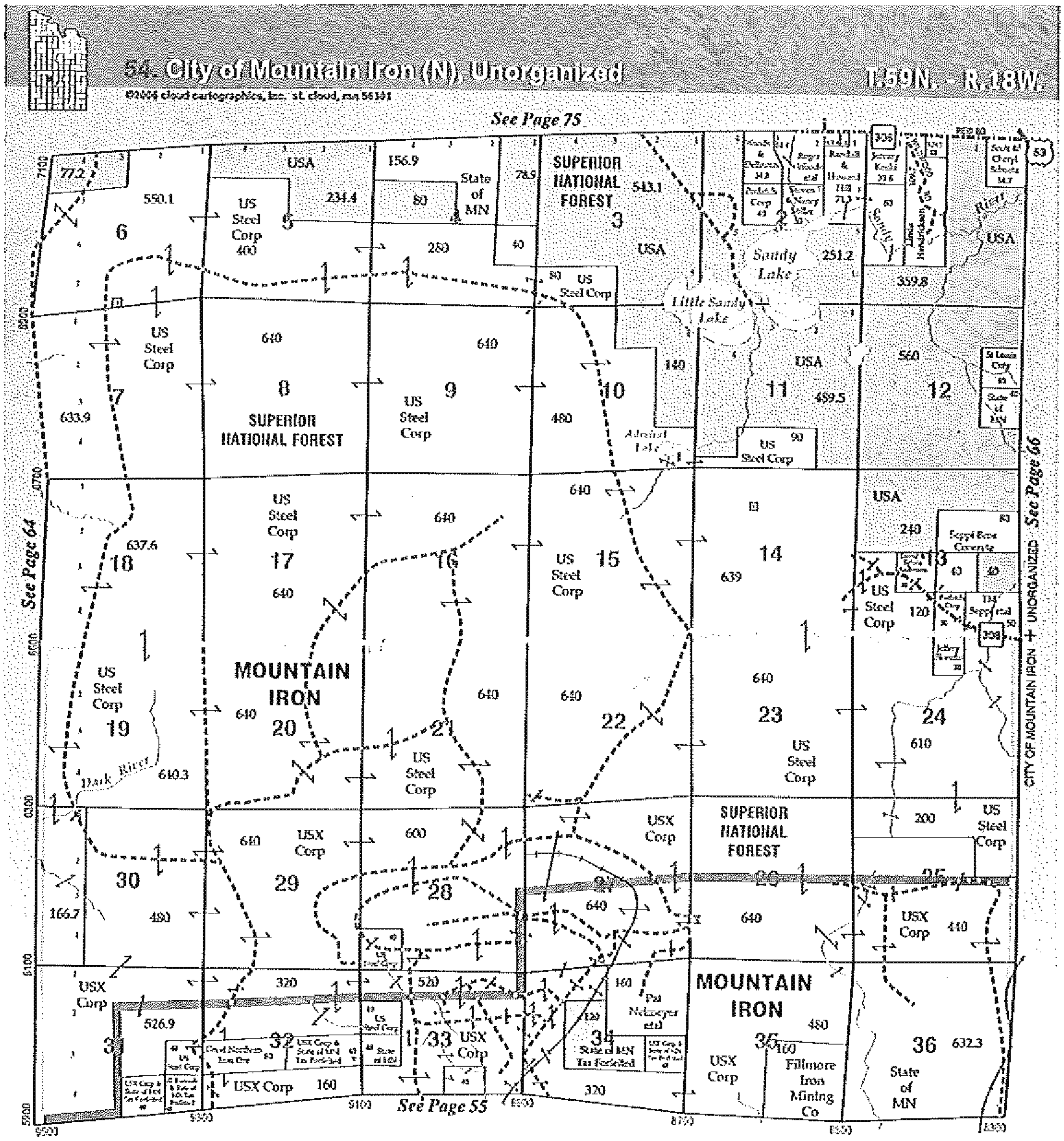

Figure 4: Sandy Lake and Little Sandy Lake (land ownership)
St. Louis County, MN, 2007 Land Atlas and Plat Book, Cloud Cartographics

Current access to the lakes is somewhat difficult. A narrow road extending from County Road 306 leads to the north side of the lakes, but crosses some private property. An informal truck trail provides a carry-down canoe access to the north shoreline of Sandy Lake. An alternative option is to utilize the existing road/trail to the bridge between the lakes. This trail was largely underwater in 2010-2016 and in a number of previous years, and access requires chest waders. Please see Appendix 1 for photographs of access points in 2016.

Sandy Lake and Little Sandy Lake (Twin Lakes) are located immediately downstream of the tailings basin for U.S. Steel's Minntac iron ore operation. Please see Figure 5.

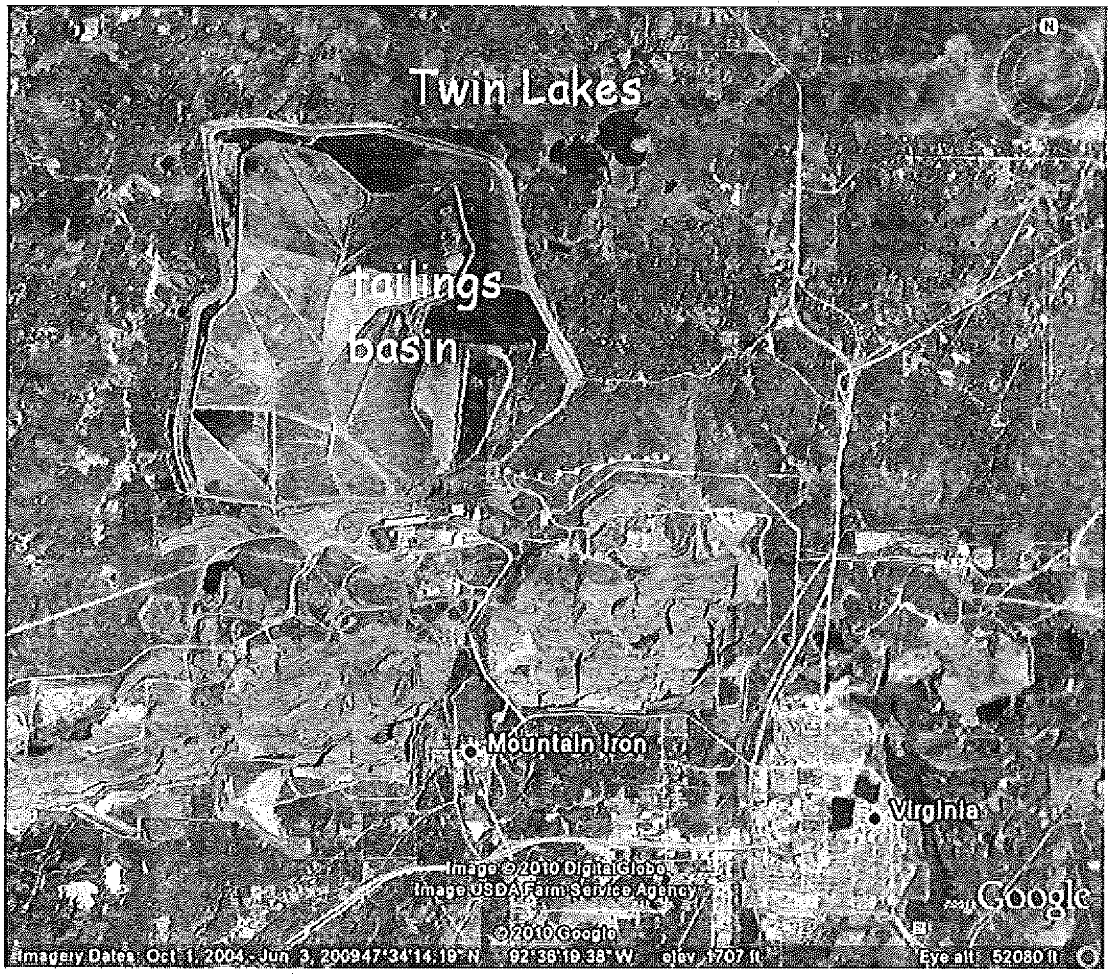

Figure 5: U.S. Steel Minntac and Twin Lakes

Water Depths

A trail and bridge bisects the connection between Sandy and Little Sandy lakes. A water depth gauge is attached to the northwest corner of the concrete bridge support. Data obtained from the Minnesota Department of Natural Resources indicates that the gauge was installed in 1991, with an elevation of 1447.1 feet above mean sea level (NGVD 29) at the zero reading on the gauge. A surveyed benchmark with an elevation of 1453.93 feet above mean sea level (NGVD 29), marked by a chiseled square in the concrete bridge support above the depth gauge, was established by the Minnesota Department of Transportation in 2008.

A local consulting firm (SEH) was retained under this monitoring project in 2010 to complete a survey to relate the depth gauge to elevation. Another benchmark was established in the same location on top of the concrete bridge support and marked by an "X" in the concrete. This benchmark has an elevation of 1454.86 feet above sea level (NAVD 88). The zero reading on the depth gauge is 1448.03 feet above mean sea level (NAVD 88). It should be noted that the two known surveyed benchmarks differ by 0.93 feet (1454.86 – 1453.93). This is due to use of the different vertical datum systems, National Geodetic Vertical Datum of 1929 (NGVD 29) versus North American Vertical Datum of 1988 (NAVD 88).

Utilizing the existing depth gauge on the bridge support, water depth readings were recorded approximately every two weeks May through early November each year in 2010-2016. The graph in Figure 6 outlines water elevations at the Twin Lakes in 2010-2016. The elevations reported are based on the benchmark established by SEH in 2010, since NAVD 88 is the current standard typically utilized. Across this time period, the highest water reading was 1452.52 feet above mean sea level (5/15/2014), and the lowest was 1450.36 feet above mean sea level (11/10/11), a difference of 2.16 feet.

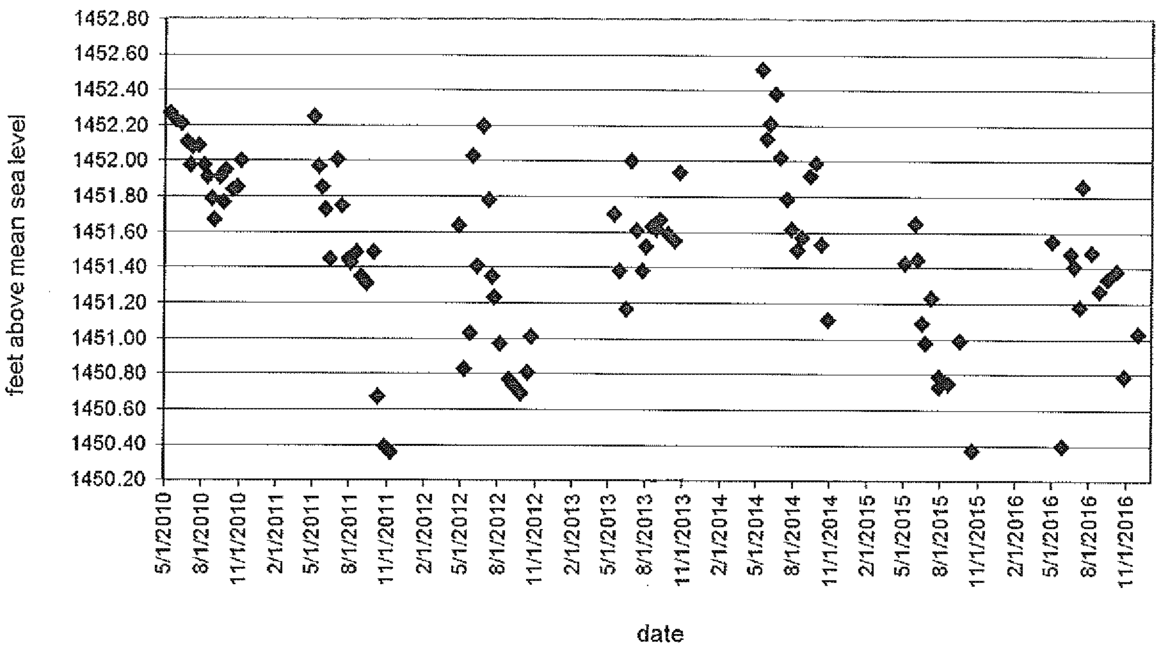

Figure 6: Water Elevation at the Twin Lakes in 2010-2015

A few readings are also available from visits completed in 2006-2008: 1451.71 (8/1/2006); 1451.48 (7/31/2007); 1451.83 (8/6/2008) feet above mean sea level based on the 2010 benchmark. Communication with the Minnesota Department of Natural Resources indicated that limited water level readings from the 1980's and 1990s may be on file at local offices. Under a separate initiative managed by U.S. Steel, an automatic data logger was installed adjacent to the bridge to track changes in water depth in 2013-2016. This data is not included in this report.

Water depth has a major influence on the success of wild rice. Wild rice grows in a variety of water depths, but 1-3 feet is typically considered prime conditions. During the vegetation surveys conducted on September 1, 2010 and June 25-26, 2013 water depths were recorded at every survey point. In the 2010 survey, mean water depths were 3.83 feet (range of 1.50-4.50 feet) in Sandy Lake and 4.23 feet (range of 2.25-5.00 feet) in Little Sandy Lake. In the 2013 survey, mean water depths were 4.07 feet (range of 1.50-5.00 feet) in Sandy Lake and 4.55 feet (range of 2.75-5.75 feet) in Little Sandy Lake.

Water depths across the Twin Lakes were typically in the range of 4-5 feet in 2010, until a decline in September. Water depths in 2011 were similar to 2010 through the middle of July 2011, but then declined in the second half of summer and dropped considerably in October 2011. In 2012, storm events in May and June caused significant increases in water depth. Water levels then declined through September 2012, with increases noted again during October 2012. In 2013, water levels declined early in the season until an increase at the end of June. Water depths remained fairly stable from early July on until an increase was observed at the end of October. Water levels in 2014 were generally high, with the highest levels observed under this program since beginning in 2010. In 2015, water levels were generally lower than previous years since 2010. Water levels were low at the end of May 2016, but then increased to higher water by mid-July before declining through the end of the open water season.

Besides upstream releases from the tailings basin and outlet conditions (such as presence of beaver dams), precipitation also impacts water levels in the Twin Lakes. Available data from the Minnesota State Climatology Office was utilized in Table 1 to summarize monthly precipitation near the Twin Lakes from May to October in 2010-2016. The precipitation data reported is based on the nearest available information reported for each month. Average monthly precipitation in inches reported for Virginia, MN is 2.73 in May, 4.64 in June, 3.87 in July, 3.74 in August, 3.44 in September, and 2.45 in October (www.weather.com). Utilizing this available information, total precipitation near the Twin Lakes was as follows:

- 23.94 inches (3.07 inches above average) from May to October 2010
- 13.73 inches (7.14 inches below average) from May to October 2011
- 23.38 inches (2.51 inches above average) from May to October 2012
- 18.38 inches (2.49 inches below average) from May to October 2013
- 21.94 inches (1.07 inches above average) from May to October 2014
- 22.10 inches (1.23 inches above average) from May to October 2015
- 25.70 inches (4.83 inches above average) from May to October 2016

Table 1: Monthly Precipitation near the Twin Lakes in May to October (2010-2016)

Month	Township, Range, Section	Distance from Twin Lakes	Precipitation (inches)
May 2010	59N 17W section 18	2 miles	2.51
June 2010	59N 17W section 18	2 miles	4.06
July 2010	59N 17W section 18	2 miles	6.69
August 2010	59N 17W section 18	2 miles	3.52
September 2010	58N 18W section 33	10 miles	4.91
October 2010	58N 18W section 33	10 miles	2.25
May 2011	59N 17W section 18	2 miles	2.80
June 2011	59N 17W section 18	2 miles	3.38
July 2011	60N 17W section 32	3 miles	1.28
August 2011	59N 17W section 18	2 miles	2.61
September 2011	59N 17W section 18	2 miles	2.04
October 2011	59N 17W section 18	2 miles	1.62
May 2012	59N 17W section 4	4 miles	7.10
June 2012	59N 17W section 18	2 miles	5.11
July 2012	60N 17W section 32	3 miles	6.67
August 2012	59N 17W section 4	4 miles	1.47
September 2012	59N 17W section 4	4 miles	1.05
October 2012	58N 18W section 33	10 miles	1.98
May 2013	59N 17W section 4	4 miles	2.44
June 2013	59N 17W section 4	4 miles	5.84
July 2013	59N 17W section 4	4 miles	3.51
August 2013	59N 17W section 4	4 miles	2.02
September 2013	59N 17W section 4	4 miles	1.44
October 2013	58N 18W section 33	10 miles	3.13
May 2014	59N 17W section 4	4 miles	4.03
June 2014	59N 17W section 4	4 miles	7.45
July 2014	59N 17W section 4	4 miles	4.35
August 2014	59N 17W section 4	4 miles	2.51
September 2014	58N 17W section 5	6 miles	1.91
October 2014	58N 18W section 33	10 miles	1.69
May 2015	59N 17W section 4	4 miles	4.89
June 2015	59N 17W section 4	4 miles	4.71
July 2015	59N 17W section 4	4 miles	2.10
August 2015	59N 17W section 4	4 miles	4.67
September 2015	59N 17W section 4	4 miles	3.24
October 2015	59N 17W section 4	4 miles	2.49
May 2016	59N 17W section 4	4 miles	1.66
June 2016	59N 17W section 4	4 miles	7.69
July 2016	59N 17W section 4	4 miles	4.28
August 2016	59N 17W section 4	4 miles	5.73
September 2016	59N 17W section 4	4 miles	4.89
October 2016	59N 17W section 4	4 miles	1.45

Minnesota State Climatology Office, Minnesota Climatology Working Group

Inlet and Outlet Field Surveys
Beaver activity can alter water levels and flow in a system, and potentially negatively impact wild rice. To document beaver activity and other general features, field surveys were completed on the inlet and outlet (Sand River) of the Twin Lakes in 2010, and only on the outlet in 2011-2016. The Minntac tailings basin is the headwaters of the Twin Lakes, with a creek entering the southeast corner of Little Sandy Lake. The Sand River leaves the northeast corner of Sandy Lake. A field survey was conducted on July 14, 2016 down the outlet of the Twin Lakes to the U.S. Highway 53 crossing. Beaver activity was the focus of the survey. No fresh beaver activity was observed, with only inactive dams and lodges present in this portion of the outlet. All dams had been cleared and opened. One site with an inactive beaver dam has grown cattails across the river, restricting flow to two small openings. Other underwater berms remained, but none were holding or controlling water levels at the time of the survey. It should be noted that the survey in 2016 was conducted during higher water due to recent rains, so some existing berms or restrictions may not have been apparent.

In addition to water entering the system from the tailings basin, the beaver activity on the outlet may also be a factor in higher water levels in the Twin Lakes. It is likely that the water levels in 2010-2016 and in recent history are contributing to the negative impacts on wild rice. Besides addressing releases from the tailings basin, beaver management (trapping, dam removal) down the outlet should be a consideration in an attempt to reduce water levels in the Twin Lakes. U.S. Steel contracted with trappers to complete beaver and dam removal beginning in spring 2015, with similar plans for 2016. Ongoing beaver management and dam removal may be needed to maintain a clear outlet.

Water Sampling and Analysis
Four water sampling locations were established in 2010. Figure 7 shows the locations of the sampling points. The locations were set in a downstream gradient and identified as:

- Twin 1 - inlet at Little Sandy Lake
- Twin 2 - middle of Little Sandy Lake
- Twin 3 - middle of Sandy Lake
- Twin 4 - outlet at Sandy Lake

Water samples were collected monthly from May through October in 2010-2014, and bi-monthly (June, August, October) in 2015-2016. Analyses were completed by Pace Analytical (formerly Era Laboratories, Inc.) in Duluth, MN. Results from 2016 are included in Table 2, and annual results of the analyses from all years (2010-2016) are included in Appendix 2.

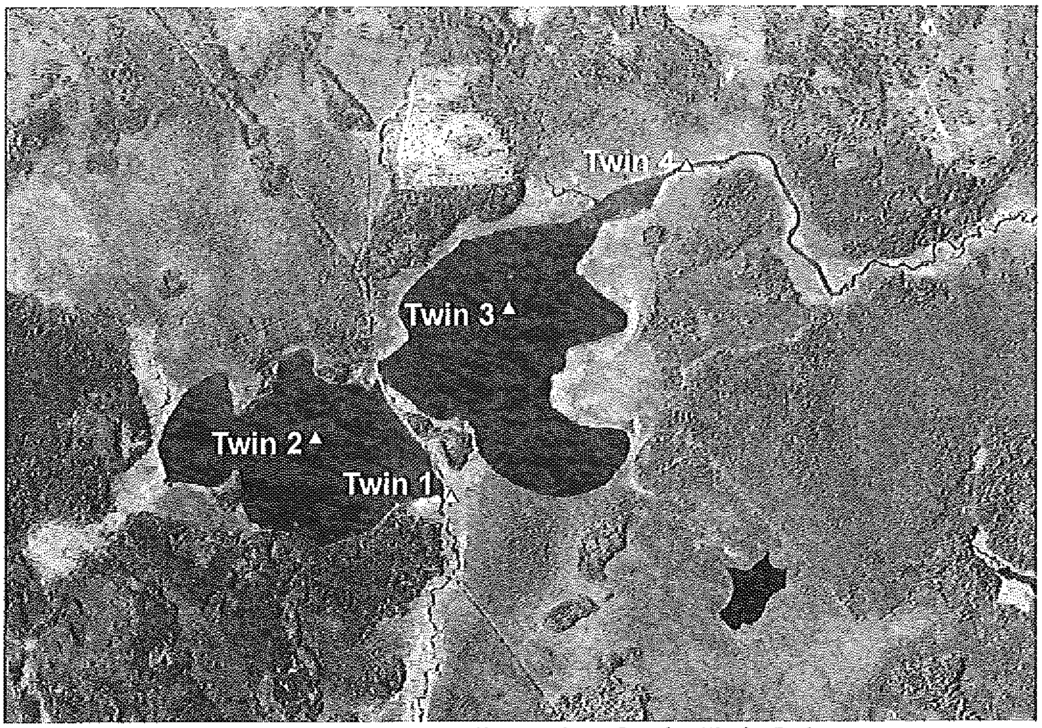

Figure 7: Water Sampling Points for the Twin Lakes

Table 2: Water Sample Analysis in the Twin Lakes (2016)

Twin 1	6/23/2016	8/24/2016	10/25/2016	units
alkalinity (as CaCO3)	114	234	200	mg/L
chloride	31.9	55.2	66.4	mg/L
color	150	200	150	Pt-Co
nitrogen, ammonia	ND	ND	ND	mg/L
nitrogen, nitrate + nitrite	ND	ND	ND	mg/L
nitrogen, total	1.0	0.85	ND	mg/L
nitrogen, total kjeldahl	1.0	0.84	ND	mg/L
pH - lab	7.3	7.3	7.6	SU
phosphorus, total	0.024	0.034	0.022	mg/L
solids, suspended volatile	ND	1.0	2.8	mg/L
solids, total dissolved	472	814	762	mg/L
solids, total suspended	1.2	1.2	5.0	mg/L
specific conductance	679	1070	1100	umhos/cm
sulfate	217	304	347	mg/L
turbidity	3.1	3.3	5.6	NTU

Twin 2	6/23/2016	8/24/2016	10/25/2016	units
alkalinity (as CaCO3)	122	194	194	mg/L
chloride	25.9	24.0	41.2	mg/L
color	40.0	300	150	Pt-Co
nitrogen, ammonia	ND	0.14	0.18	mg/L
nitrogen, nitrate + nitrite	ND	ND	0.020	mg/L
nitrogen, total	0.82	1.3	0.73	mg/L
nitrogen, total kjeldahl	0.82	1.3	0.71	mg/L
pH - lab	7.9	8.1	8.2	SU
phosphorus, total	0.014	0.023	0.010	mg/L
solids, suspended volatile	ND	2.0	ND	mg/L
solids, total dissolved	428	486	570	mg/L
solids, total suspended	1.8	2.4	1.0	mg/L
specific conductance	628	640	818	umhos/cm
sulfate	194	126	211	mg/L
turbidity	1.8	3.2	1.7	NTU

Twin 3	6/23/2016	8/24/2016	10/25/2016	units
alkalinity (as CaCO3)	93.2	145	158	mg/L
chloride	24.5	19.2	33.4	mg/L
color	90.0	375	100	Pt-Co
nitrogen, ammonia	ND	0.40	ND	mg/L
nitrogen, nitrate + nitrite	ND	ND	ND	mg/L
nitrogen, total	0.68	1.6	0.81	mg/L
nitrogen, total kjeldahl	0.67	1.5	0.80	mg/L
pH - lab	8.0	7.8	8.3	SU
phosphorus, total	0.011	0.027	0.012	mg/L
solids, suspended volatile	ND	1.2	ND	mg/L
solids, total dissolved	348	386	454	mg/L
solids, total suspended	1.0	1.0	ND	mg/L
specific conductance	525	481	663	umhos/cm
sulfate	158	82.7	148	mg/L
turbidity	1.1	3.7	1.9	NTU

Twin 4	6/23/2016	8/24/2016	10/25/2016	units
alkalinity (as CaCO3)	89.0	132	143	mg/L
chloride	22.7	17.5	30.4	mg/L
color	110	300	150	Pt-Co
nitrogen, ammonia	ND	0.34	0.18	mg/L
nitrogen, nitrate + nitrite	ND	ND	ND	mg/L
nitrogen, total	0.63	1.4	0.73	mg/L
nitrogen, total kjeldahl	0.63	1.4	0.72	mg/L
pH - lab	7.8	7.8	8.1	SU
phosphorus, total	0.014	0.029	0.015	mg/L
solids, suspended volatile	ND	1.0	1.0	mg/L
solids, total dissolved	314	360	410	mg/L
solids, total suspended	1.6	1.0	1.6	mg/L
specific conductance	477	435	616	umhos/cm
sulfate	138	70.9	132	mg/L
turbidity	2.1	6.8	2.8	NTU

In comparison with other lakes containing wild rice in the region, some parameters are of note in the Twin Lakes. Most notable are elevated levels of alkalinity, chloride, total dissolved solids, specific conductance, and sulfate. Sulfate levels ranged from 210 mg/L to 661 mg/L across all samples in 2010, before the installation of the seep collection system at the U.S. Steel Minntac tailings basin. After the system was in operation, sulfate ranged from 61.4 to 561 mg/L in 2011, from 38 to 275 mg/L in 2012, from 36 to 650 mg/L in 2013, from 44 to 419 mg/L in 2014, from 45.6 to 590 mg/L in 2015, and from 70.9 to 347 mg/L in 2016. Table 3 displays average sulfate concentrations at each sampling point in 2010-2016. A Minnesota water quality standard exists for sulfate of *"10 mg/L, applicable to water used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels"* (Minnesota Rules, part 7050.0224, subp. 2).

Table 3: Average Sulfate Concentrations at Twin Lakes Sampling Points (ranges in parentheses)

	2010 average sulfate (mg/L)	2011 average sulfate (mg/L)	2012 average sulfate (mg/L)	2013 average sulfate (mg/L)	2014 average sulfate (mg/L)
Twin 1	483 (360-661)	357 (208-561)	207 (137-275)	355 (215-650)	301 (180-419)
Twin 2	353 (280-475)	164 (130-247)	144 (87-210)	195 (149-261)	172 (128-274)
Twin 3	280 (250-310)	118 (103-166)	97 (72.6-160)	129 (118-140)	114 (96-172)
Twin 4	234 (210-252)	84 (61.4-127)	66 (38-101)	89 (36-120)	70 (44-100)

	2015 average sulfate (mg/L)	2016 average sulfate (mg/L)
Twin 1	460 (386-590)	289 (217-347)
Twin 2	295 (253-360)	177 (126-211)
Twin 3	217 (171-270)	130 (82.7-158)
Twin 4	145 (45.6-220)	114 (70.9-138)

To help determine if the seep collection system was a factor in reducing sulfate levels in the Twin Lakes at the start of operation in late 2010, paired two-sample, one-tailed t-tests were performed ($\alpha = 0.05$) comparing data from 2010 to 2011. Analyses were based on water quality results from six samples taken at each location (Twin 1, Twin 2, Twin 3, Twin 4) per year.

On average, sulfate levels measured in 2011 were significantly less than sulfate levels measured in 2010 at sample locations Twin 2 (164.3 mg/L < 352.5 mg/L, $p = 0.0011$, $t = 5.72$), Twin 3 (117.5 mg/L < 279.5 mg/L, $p = 0.0001$, $t = 10.09$) and Twin 4 (83.9 mg/L < 234.2mg/L, $p = 0.0001$, $t = 11.07$). The average sulfate level measured at Twin 1 in 2011 was lower than the level measured in 2010 (356.7 mg/L < 482.3 mg/L), but the difference was not significant ($p = 0.0780$, $t = 1.67$). These analyses suggest a decrease in sulfate concentration at each sample location after the first year of seep collection operation.

From 2010-2016, sulfate levels have trended down slightly in the Twin Lakes (Figure 8). After the seep collection system began operation, sulfate levels in 2011-2016 have varied and showed a trend upward (Figure 9).

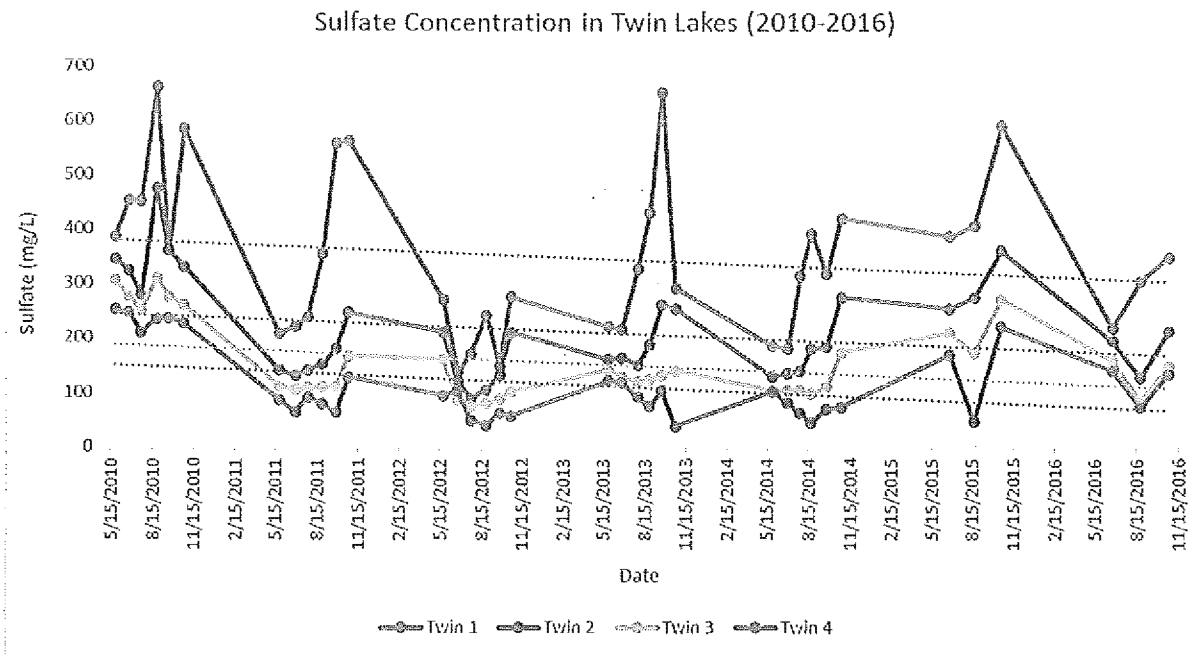

Figure 8: Sulfate Concentration in Twin Lakes (2010-2016)

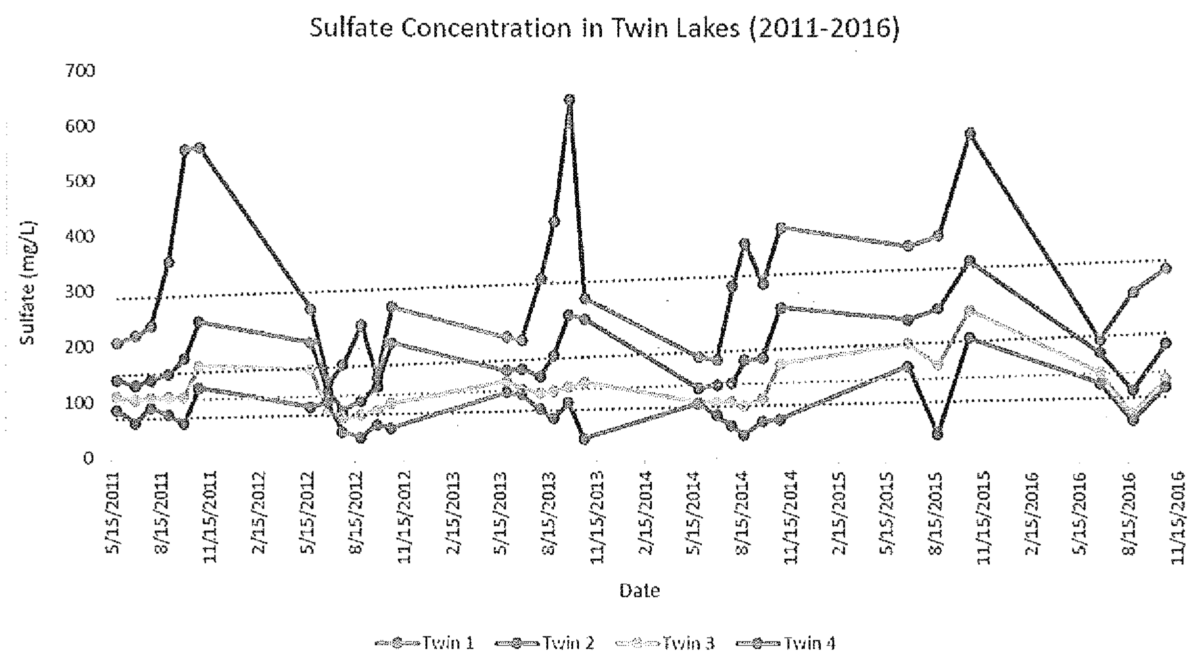

Figure 9: Sulfate Concentration in Twin Lakes (2011-2016)

In addition to monthly water sampling in the Twin Lakes, one sampling event occurred at three locations each October in 2010-2016 in the system downstream to Lake Vermilion. Sampling was completed in the Sand River (State Highway 169 crossing), Pike River (County Road 367), and the Pike River Flowage (State Highway 1 public access). Sampling locations are shown in Figure 10.

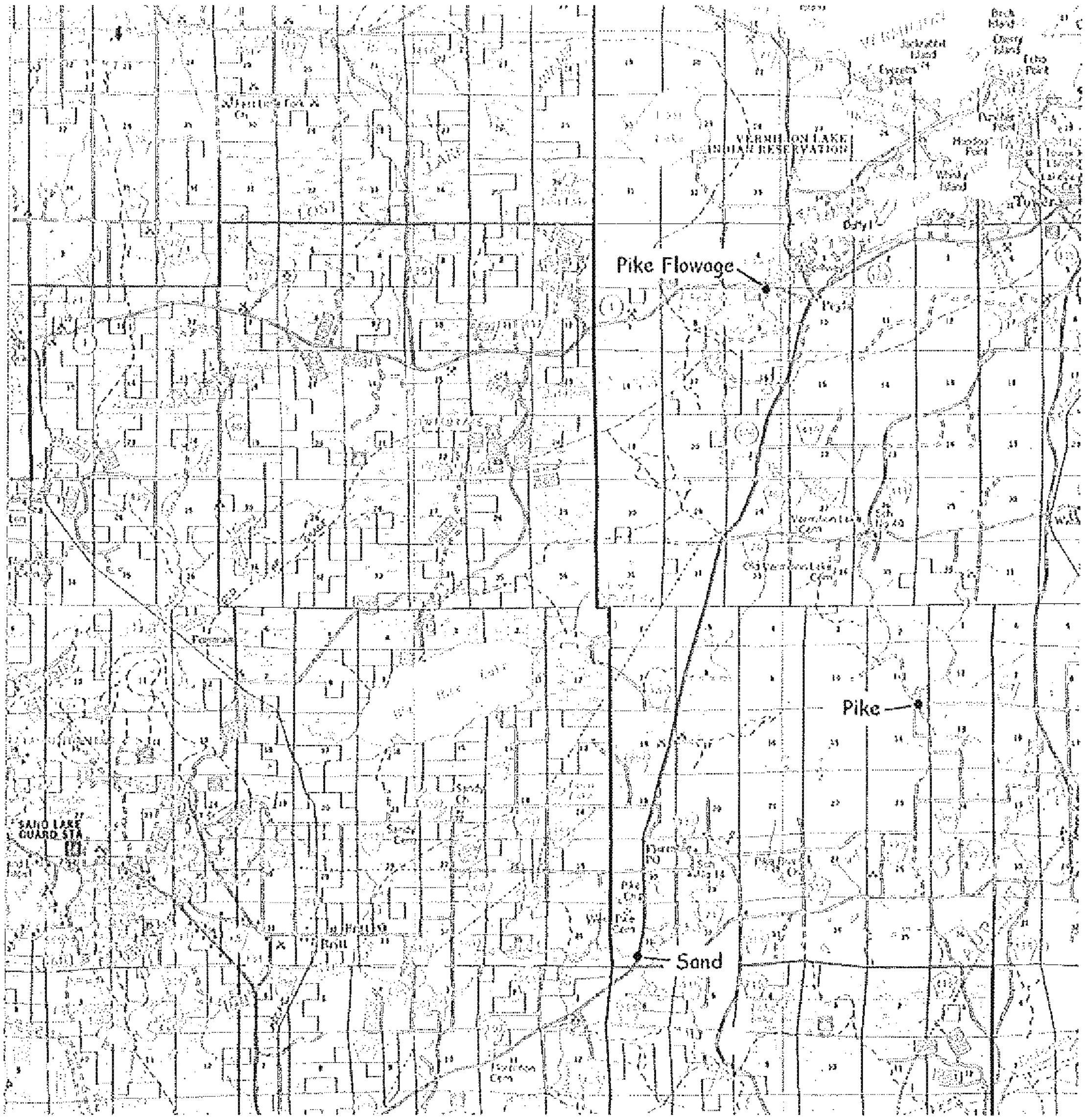

Figure 10: Water Sampling Points in the Sand River, Pike River, and Pike River Flowage
United States Department of Agriculture, U.S. Forest Service, Superior National Forest map, 2003

Table 4 displays analysis results in 2016, and Appendix 2 includes annual results of the analyses from all years (2010-2016) for the downstream sampling locations. Sample analysis indicated generally declining levels of several parameters including alkalinity, chloride, total dissolved solids, specific conductance, and sulfates moving downstream through the system. When sampling was conducted at all points on the same date, sulfate concentrations from the inlet at Little Sandy Lake to the Pike River Flowage ranged from 584-27 mg/L on 10/25/2010, from 561-19 mg/L on 10/26/2011, from 275-15 mg/L on 10/22/2012, from 291-7.1 mg/L on 10/23/13, from 419-11 mg/L on 10/27/14, from 590-31.9 mg/L on 10/19/2015, and from 347-17.9 mg/L on 10/25/2016.

Table 4: Water Sample Analysis in the Sand River, Pike River, and Pike River Flowage (2016)

10/25/2016	Sand	Pike	Pike Flowage	units
alkalinity (as CaCO3)	84.9	70.4	62.1	mg/L
chloride	28.3	18.9	17.3	mg/L
color	200	150	200	Pt-Co
nitrogen, ammonia	0.10	ND	ND	mg/L
nitrogen, nitrate + nitrite	0.040	0.068	0.068	mg/L
nitrogen, total	0.91	0.71	0.91	mg/L
nitrogen, total kjeldahl	0.87	0.64	0.84	mg/L
pH - lab	7.4	7.6	7.6	SU
phosphorus, total	0.029	0.021	0.025	mg/L
solids, suspended volatile	1.6	2.4	ND	mg/L
solids, total dissolved	228	174	184	mg/L
solids, total suspended	2.6	5.2	1.4	mg/L
specific conductance	341	245	218	umhos/cm
sulfate	43.8	22.1	17.9	mg/L
turbidity	6.8	6.0	4.1	NTU

Vegetation Surveys

Known aquatic vegetation surveys were completed in 1966 and 1987 at the Twin Lakes by the Minnesota Division of Game and Fish, and Minnesota Department of Natural Resources respectively. The 1966 survey described Sandy Lake with dense wild rice over the entire lake, and Little Sandy Lake with moderately dense rice over the entire lake. The report also mentions that the wild rice is harvested at the lakes when the crop is adequate. Results from the 1987 survey indicated that the aquatic vegetation changed little since the 1966 survey, with one noticeable exception. Wild rice for all practical purposes was absent from both lakes. Two other changes occurred: the water levels were considerably higher in 1987 than in 1966 (approximately 2 feet), and the water clarity improved dramatically (from 1.3 feet to approximately 6 feet). The report also describes the rice crop at Twin Lakes in some years from 1966 to 1987: 1966-fair, 1968-fair, 1970-good, 1972-good, 1973-fair, 1977-poor, 1978-poor, 1980-fair, 1981-fair, 1982-poor, 1984-poor, 1985-poor, 1986-poor, 1987-poor.

With the decline in wild rice abundance, some management activities were undertaken to improve production at the Twin Lakes. Beaver management (trapping, dam blasting) was conducted on the system periodically in the 1980s through the mid-1990s by the Minnesota Department of Natural Resources. In addition, information indicates that some wild rice seeding was conducted in 1991 and 1992. However, limited success in restoring wild rice was noted. Staff from the Minnesota Department of Natural Resources report an area of sparse wild rice was found near the outlet in 1993, and believe that was the last time anything that could be referred to as a "bed of wild rice" was on the lakes. Wild rice was found only in trace quantities within the lakes in 2000 and 2001 by the Bois Forte Department of Natural Resources (reported in Minntac Water Inventory Reduction EIS, September 2004). The 1854 Treaty Authority conducted a survey to document wild rice presence on the Twin Lakes on August 1, 2006. Some individual wild rice plants were found along portions of the shoreline of Sandy Lake, and along portions of the north shore of Little Sandy Lake. Please see Figure 11.

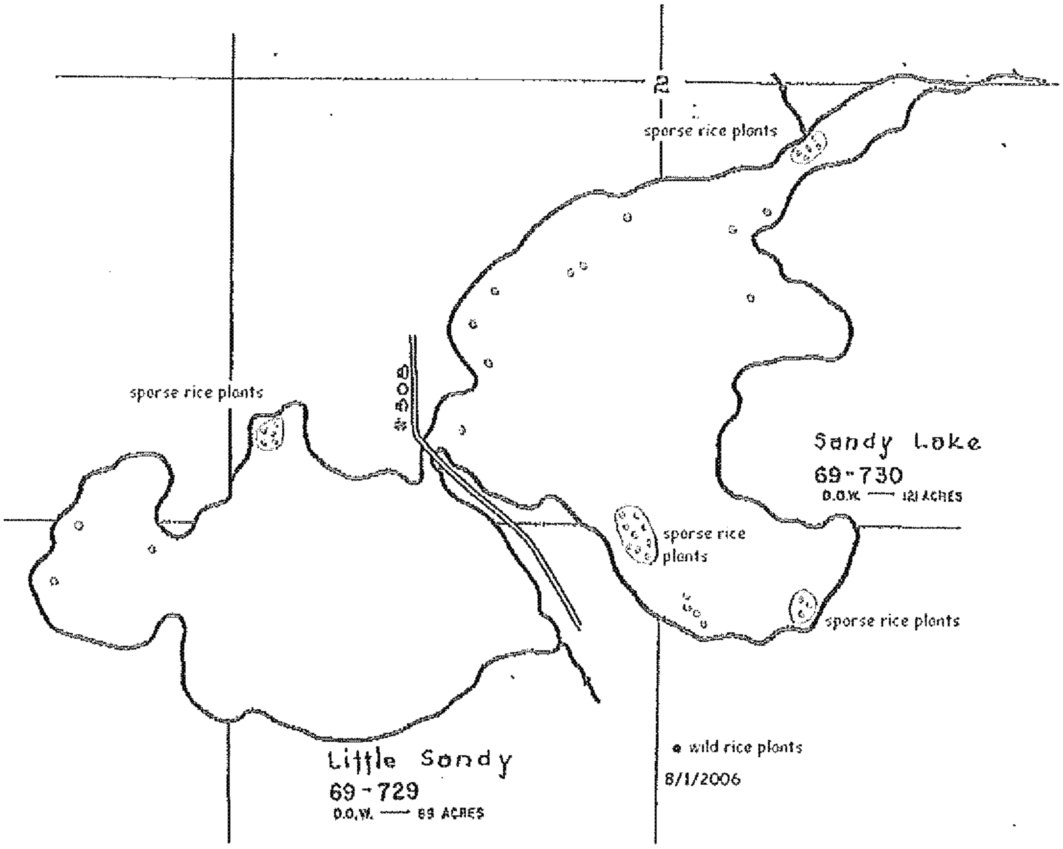

Figure 11: Wild Rice Locations in the Twin Lakes in 2006

Another field visit, but not a complete survey of both lakes, on July 31, 2007 found a few scattered wild rice plants along the west shoreline of Sandy Lake near the bridge. Please see Figure 12. No wild rice was evident viewing from the bridge on August 6, 2008.

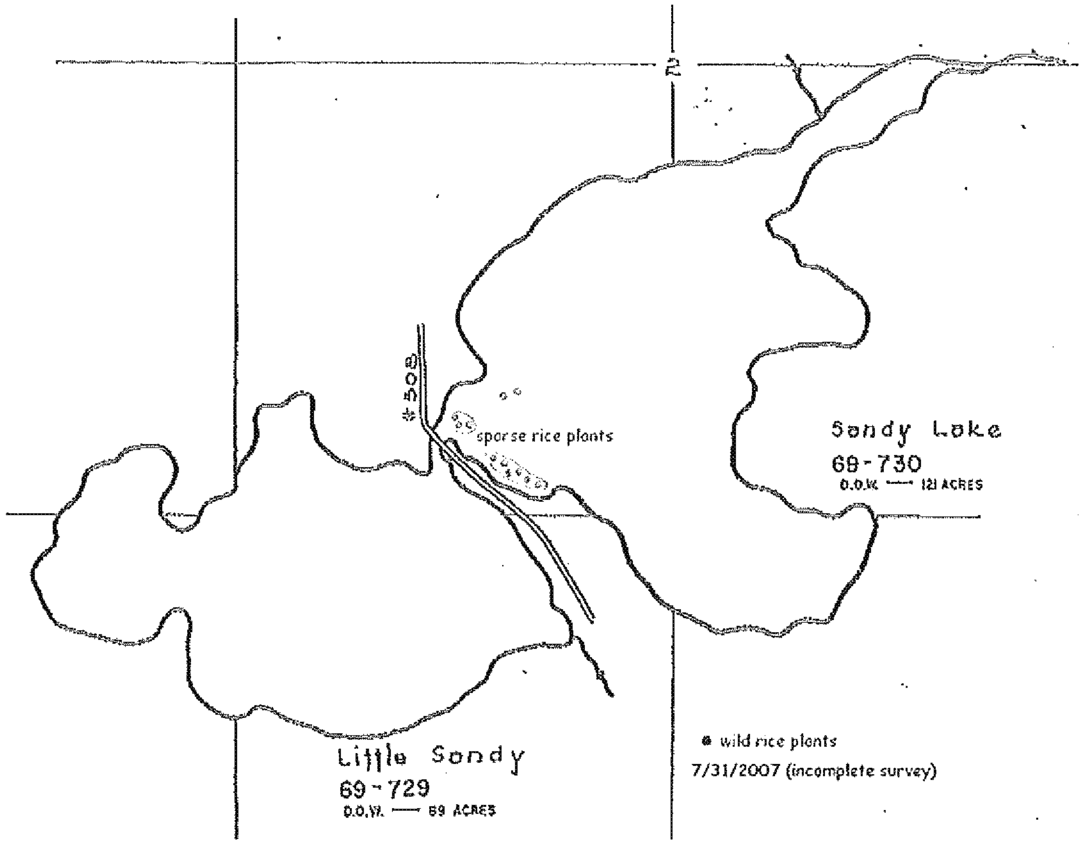

Figure 12: Wild Rice Locations in the Twin Lakes in 2007 (not complete survey of lakes)

To document conditions at the Twin Lakes, an aquatic vegetation survey was completed on both lakes on September 1, 2010. The survey was conducted by the Minnesota Department of Natural Resources Shallow Lakes Program, following their standard protocol for lake surveys. In general, the survey consisted of identifying aquatic vegetation (and recording other characteristics such as water depth, water clarity, and bottom type) at a grid of survey points across the lakes. Emergent and floating-leaf vegetation was identified by sight, and a sampling hook was used to gather submerged vegetation for identification. On the Twin Lakes, 49 survey points were established on Sandy Lake, and 44 points on Little Sandy Lake. The Minnesota Department of Natural Resources repeated the aquatic vegetation survey on June 25-26, 2013. Vegetation found and frequency observed at sampling points in the lakes during the 2010 and 2013 surveys are listed in Table 5. Final reports on both vegetation surveys have been completed by the Minnesota Department of Natural Resources.

Table 5: Vegetation in the Twin Lakes in 2010 and 2013

Sandy Lake (9/1/2010)		Sandy Lake (6/26/2013)	
vegetation species	frequency	vegetation species	frequency
Muskgrass *(Chara spp.)*	75.5%	Northern Water Milfoil *(Myriophyllum sibiricum)*	52.1%
Northern Water Milfoil *(Myriophyllum sibiricum)*	36.7%	Sago Pondweed *(Stuckenia pectinata)*	39.6%
Sago Pondweed *(Stuckenia pectinata)*	34.7%	Muskgrass *(Chara spp.)*	37.5%
Coontail *(Ceratophyllum demersum)*	10.2%	Greater Bladderwort *(Utricularia vulgaris)*	25.0%
no vegetation found	10.2%	Common Yellow Waterlily *(Nuphar variegata)*	18.8%
Emergent Burreed Group *(Sparganium EM spp.)*	6.1%	White-stem Pondweed *(Potamogeton praelongus)*	8.3%
White Waterlily *(Nymphaea odorata)*	6.1%	Flat-stem Pondweed *(Potamogeton zosteriformis)*	6.3%
Greater Bladderwort *(Utricularia vulgaris)*	4.1%	White Waterlily *(Nymphaea odorata)*	6.3%
Fries Pondweed *(Potamogeton friesii)*	4.1%	Narrowleaf Cattail Group *(Typha angustifolia or glauca)*	4.2%
Bushy Pondweed *(Najas flexilis)*	4.1%	no vegetation found	4.2%
Narrowleaf Cattail Group *(Typha angustifolia or glauca)*	2.0%	Coontail *(Ceratophyllum demersum)*	4.2%
Clasping-leaf Pondweed *(Potamogeton richardsonii)*	2.0%	Robbins Pondweed *(Potamogeton robbinsii)*	2.1%
White-stem Pondweed *(Potamogeton praelongus)*	2.0%	Curly-leaf Pondweed *(Potamogeton crispus)*	2.1%
Watermoss Group *(Drepanocladus or Fontinalis spp.)*	2.0%	Water Shield *(Brasenia schreberi)*	2.1%
Little Sandy Lake (9/1/2010)		**Little Sandy Lake (6/25/2013)**	
vegetation species	frequency	vegetation species	frequency
Northern Water Milfoil *(Myriophyllum sibiricum)*	84.1%	Northern Water Milfoil *(Myriophyllum sibiricum)*	79.5%
Muskgrass *(Chara spp.)*	81.8%	Sago Pondweed *(Stuckenia pectinata)*	56.8%
Sago Pondweed *(Stuckenia pectinata)*	27.3%	Greater Bladderwort *(Utricularia vulgaris)*	31.8%
Fries Pondweed *(Potamogeton friesii)*	13.6%	Coontail *(Ceratophyllum demersum)*	20.5%
Coontail *(Ceratophyllum demersum)*	9.1%	Common Yellow Waterlily *(Nuphar variegata)*	15.9%
Greater Bladderwort *(Utricularia vulgaris)*	6.8%	Muskgrass *(Chara spp.)*	15.9%
Emergent Burreed Group *(Sparganium EM spp.)*	6.8%	Narrowleaf Cattail Group *(Typha angustifolia or glauca)*	4.5%
Narrowleaf Cattail Group *(Typha angustifolia or glauca)*	4.5%	Floatingleaf Burreed Group *(Sparganium FL spp.)*	4.5%
Common Yellow Waterlily *(Nuphar variegata)*	2.3%	Spikerush Group *(Eleocharis spp.)* *(Eleocharis spp.)*	4.5%
		no vegetation found	2.3%

Present but not observed at any sample points: Wild Rice *(Zizania palustris)*, Pickerelweed *(Pontederia cordata)*, Arrowhead Group *(Sagittaria spp.)*, Bulrush Group *(Scirpus spp.)*

During the vegetation survey on September 1, 2010, specific locations containing wild rice were recorded. Two areas on Sandy Lake contained wild rice plants. Wild rice plants (<25) were located on the northeast arm toward the outlet. Additional wild rice plants (<50) were located on the southwest end of the lake. No wild rice was found in Little Sandy Lake in 2010. Please see Figure 13 for wild rice locations in 2010.

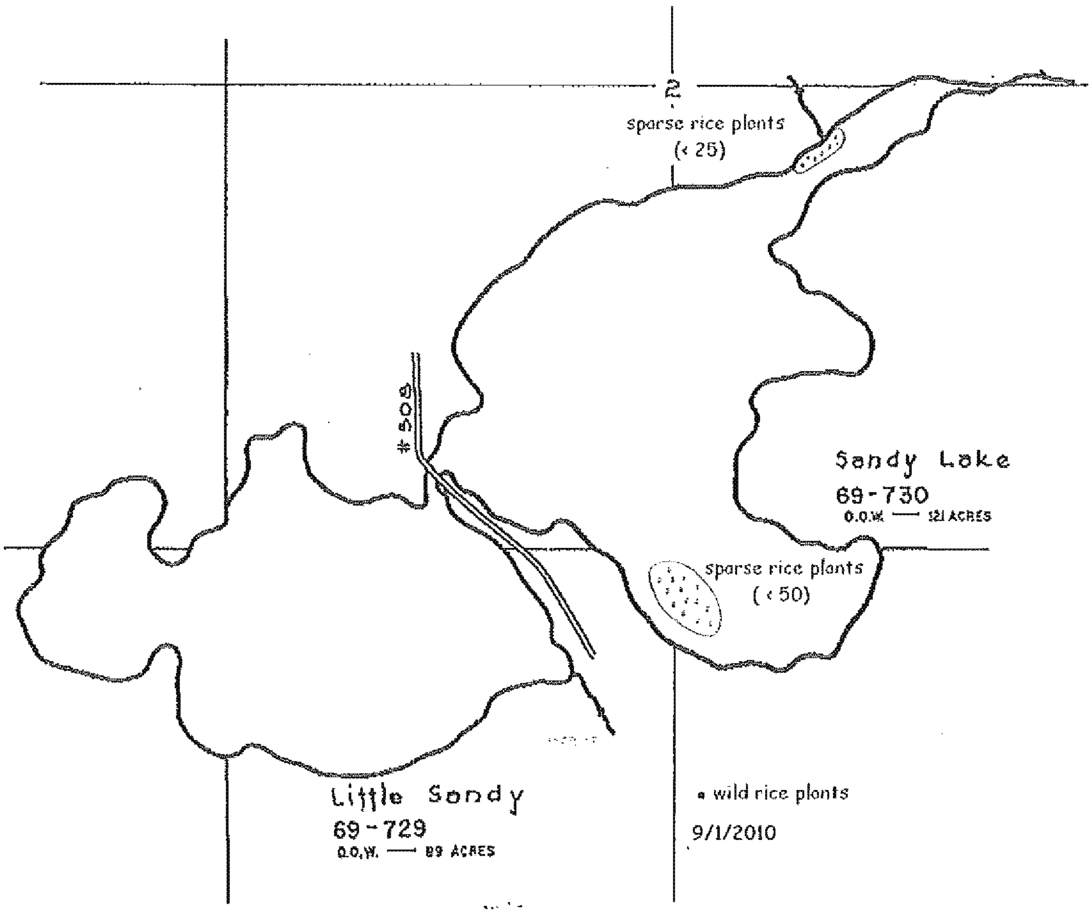

Figure 13: Wild Rice Locations in the Twin Lakes in 2010

A survey was conducted on August 29, 2011 to document wild rice presence on the lakes. Wild rice plants (<50) were located on the northeast arm of Sandy Lake toward the outlet. Additional wild rice plants (<40) were located on the southwest end of the lake. No wild rice was found in Little Sandy Lake in 2011. Please see Figure 14 for wild rice locations in 2011.

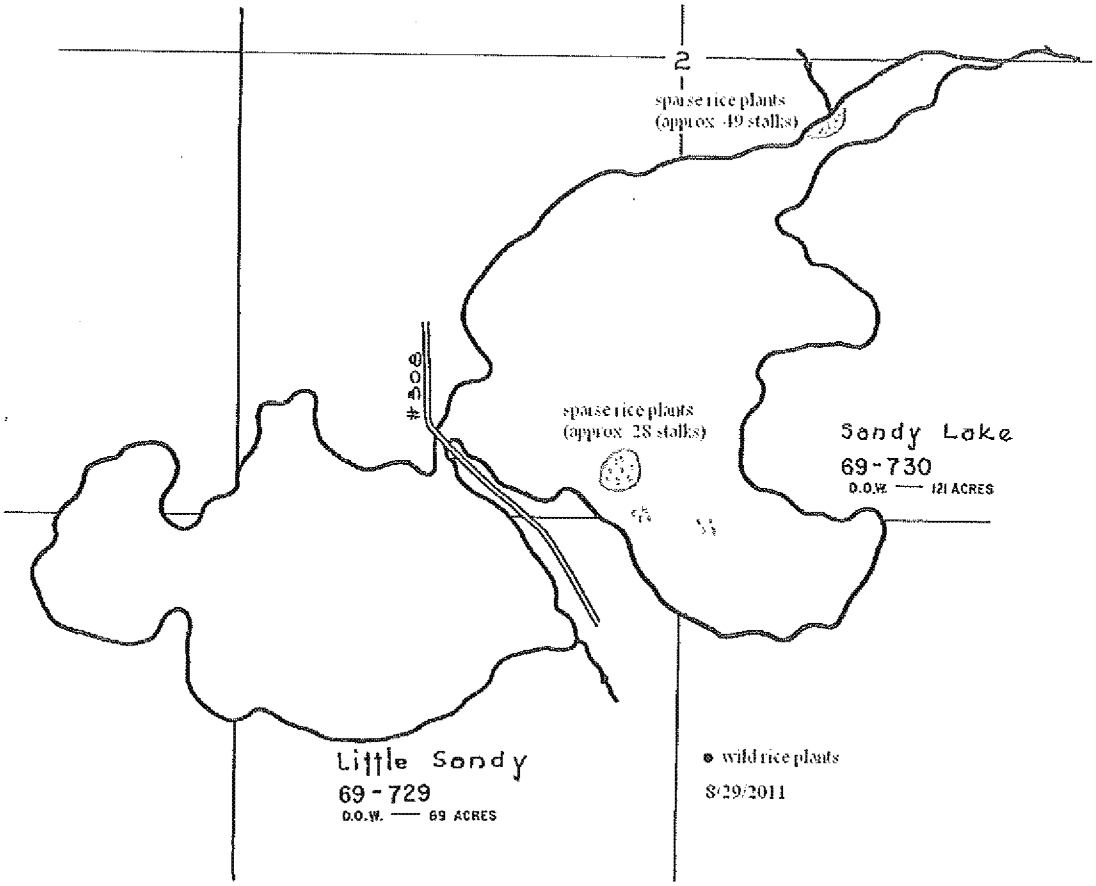

Figure 14: Wild Rice Locations in the Twin Lakes in 2011

In 2012, the survey to document wild rice presence on the lakes was conducted on August 27th. As in 2010 and 2011, wild rice plants (<50) were located on the northeast arm of Sandy Lake toward the outlet. Additional wild rice plants were located along portions of the eastern shore and southern end of the lake. For the first time documented since 2006 (although not surveyed in 2007-2009), wild rice was found in Little Sandy Lake in 2012 with two stalks growing along shore in the northwest bay of the lake. Please see Figure 15 for wild rice locations in 2012.

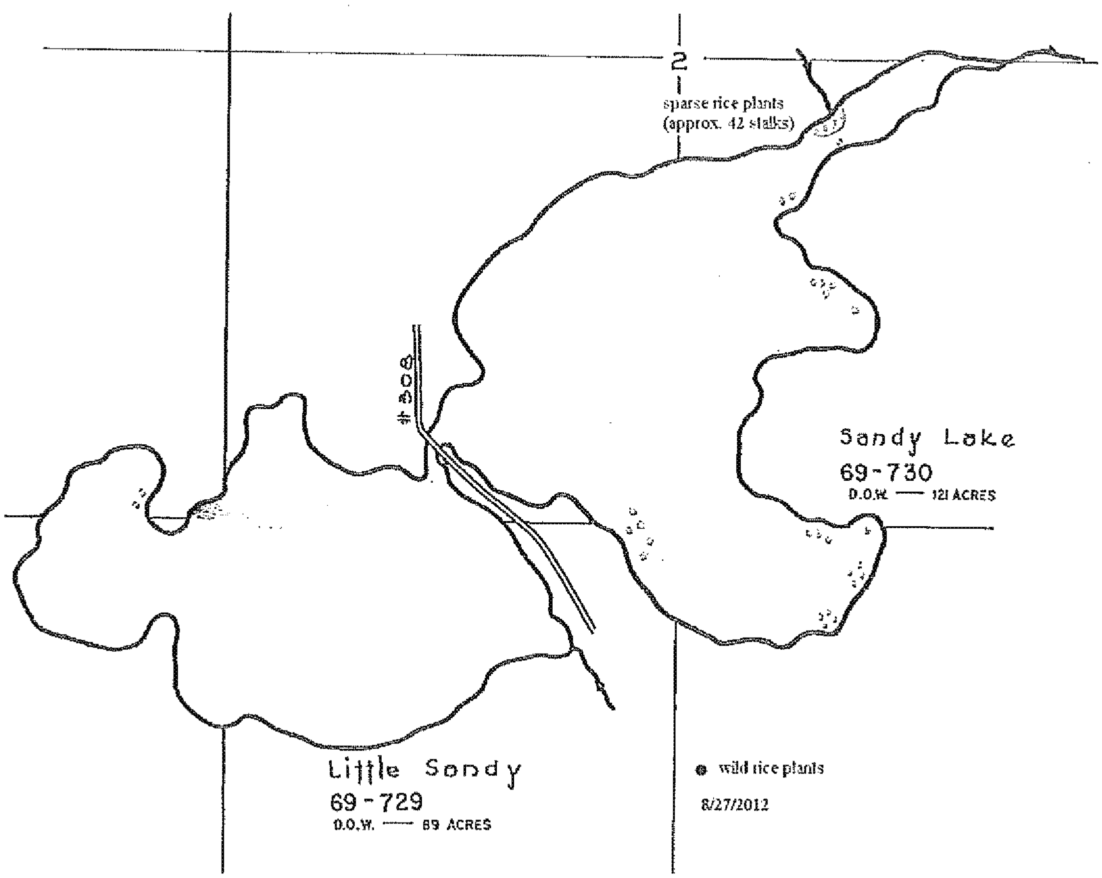

Figure 15: Wild Rice Locations in the Twin Lakes in 2012

The 2013 survey of wild rice presence was completed on August 26th. Some scattered wild rice plants were found along the northeast, east, and south shores of Sandy Lake. One notable difference from 2010-2012 was that no wild rice was observed in the northeast arm of Sandy Lake at the mouth of a small creek entering the system. One stalk of wild rice was found in Little Sandy Lake in 2013. Please see Figure 16 for wild rice locations in 2013.

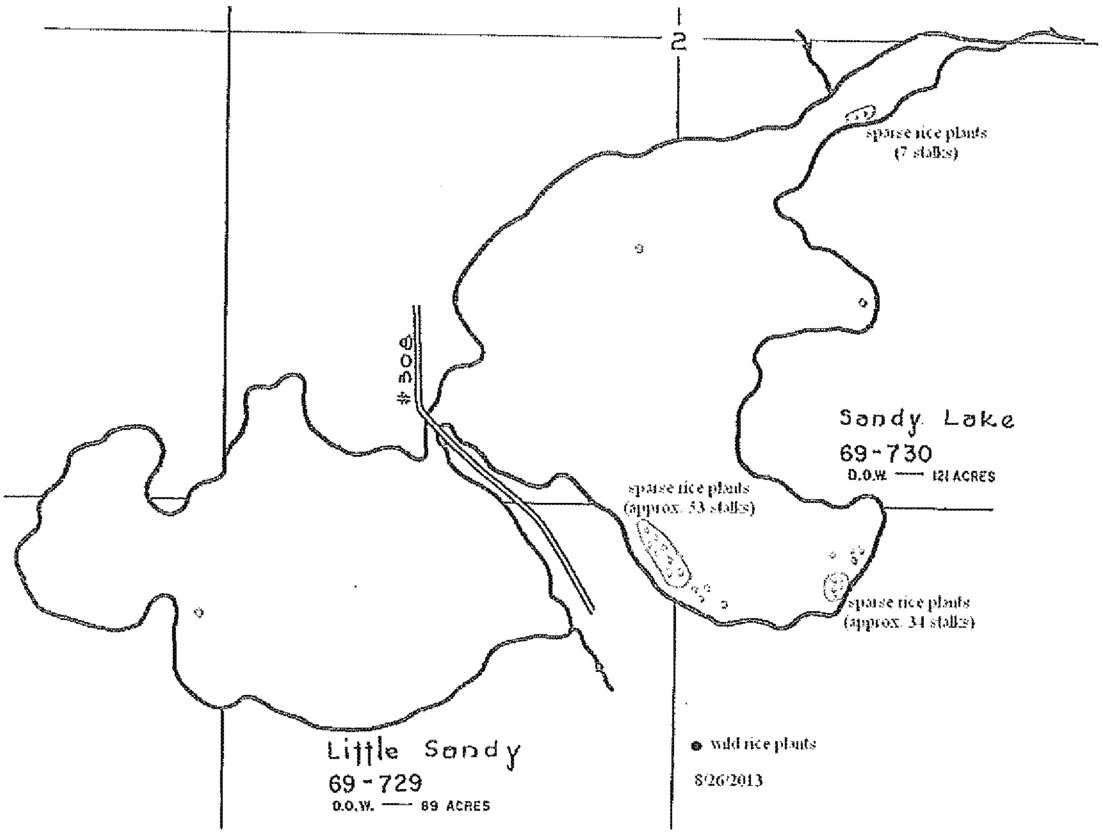

Figure 16: Wild Rice Locations in the Twin Lakes in 2013

In 2014, a total of 16 wild rice stalks was observed on Sandy Lake during the survey completed on August 21st. Wild rice plants were found along the southern shore of the lake, with one plant (short, just standing out of water) located in the northwest portion. For the first time since annual monitoring began in 2010, no wild rice was observed in the northeast arm of Sandy Lake. No wild rice was found in Little Sandy Lake in 2014. Please see Figure 17 for wild rice locations in 2014.

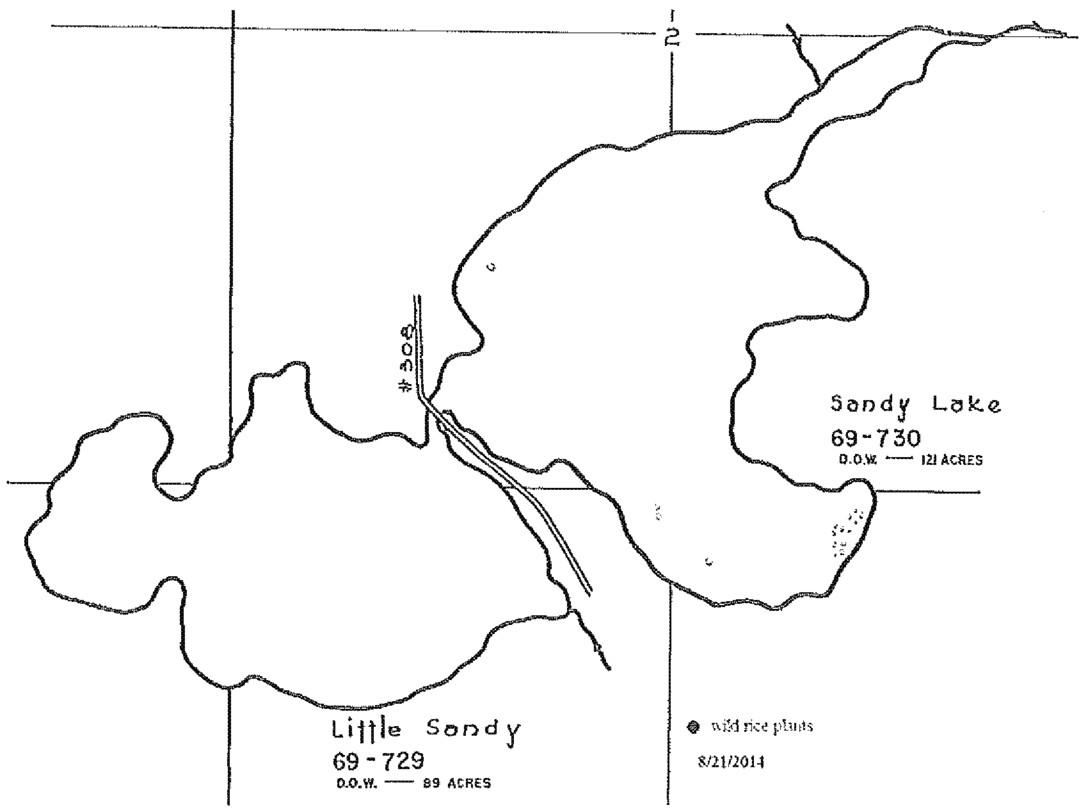

Figure 17: Wild Rice Locations in the Twin Lakes in 2014

In 2015, the survey for wild rice was conducted on August 20th. On Sandy Lake, a total of 36 stalks of wild rice was observed. Ten stalks were present in the northeast arm near the outlet, and one group of 26 stalks was found along the south shore. Some stalks were just standing out of the water or broken, and likely did not fully mature. No wild rice was seen in Little Sandy Lake in 2015. Please see Figure 18 for wild rice locations in 2015. U.S. Steel Minntac completed wild rice seeding on 10/23/15 using seed collected from the Sand River (approximately 40 lbs.). The seeding occurred in six small test plots, three in each lake. Success of wild rice growth was evaluated in 2016.

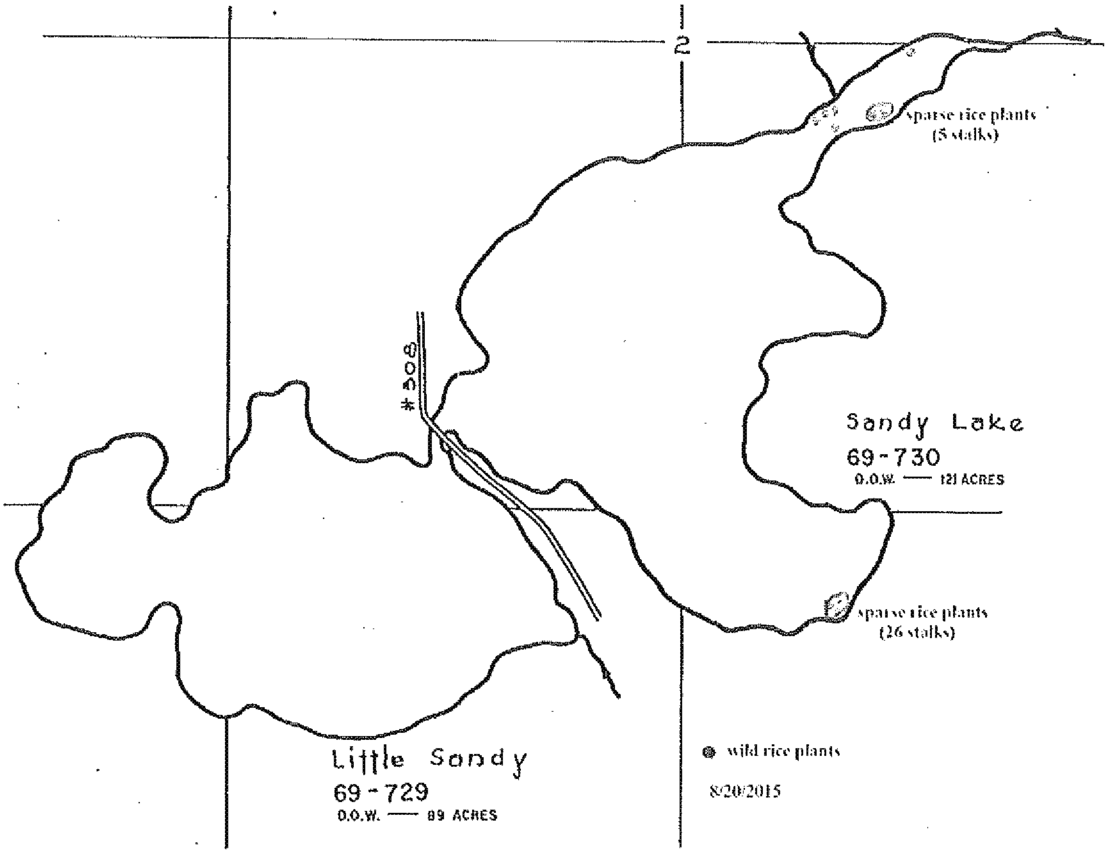

Figure 18: Wild Rice Locations in the Twin Lakes in 2015

During the 2016 wild rice survey completed on August 24th, wild rice was observed on both lakes. On Sandy Lake, 26 stalks of wild rice were seen outside of seeding plots. No wild rice was seen outside of seeding plots on Little Sandy Lake. Please see Figure 19 for wild rice locations in 2016. U.S. Steel Minntac completed wild rice seeding in fall 2015 in six test plots. Wild rice was observed in four of these plots, indicated on Figure 19.

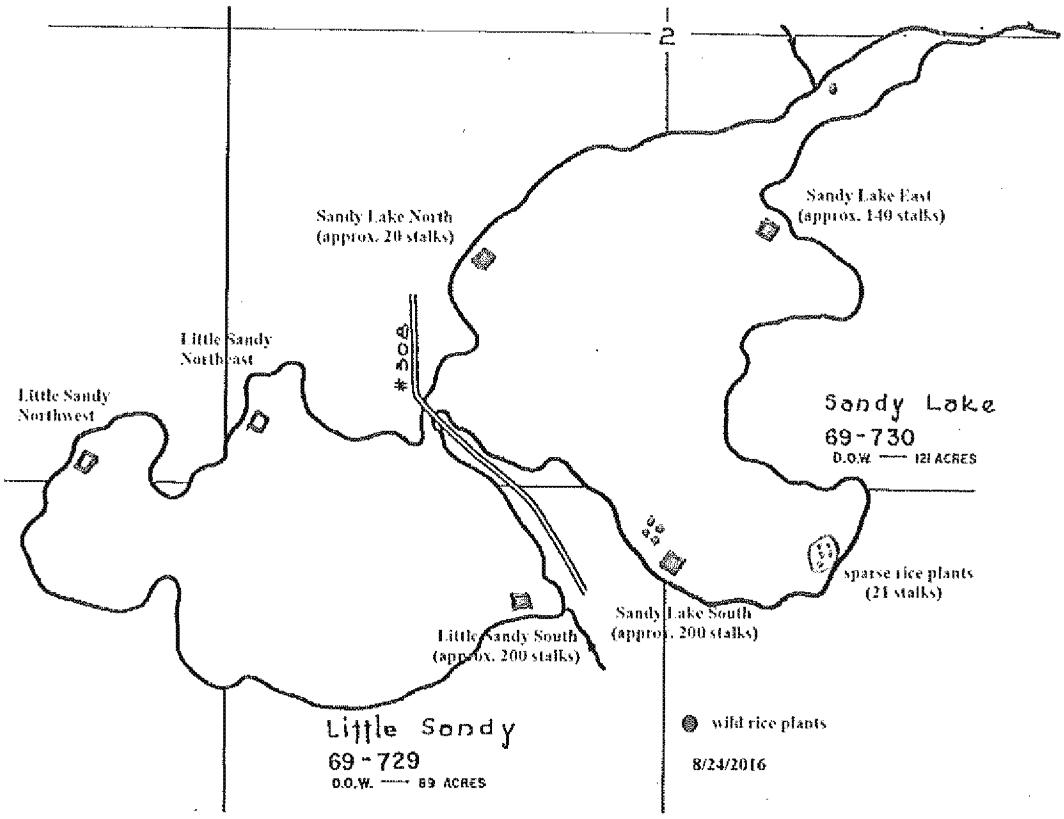

Figure 19: Wild Rice Locations in the Twin Lakes in 2016

Aerial Survey

To view the system and to document wild rice presence from the Minntac tailings basin downstream to Lake Vermilion, an aerial survey was conducted by helicopter each year in 2010-2014. In 2015-2016, flights were not conducted due to budget constraints. Flights began at the tailings basin, continued downstream to the Twin Lakes, followed the Sand River to its confluence with the Pike River, and then continued down the Pike River to the Pike River Flowage at its entrance into Lake Vermilion. In addition to taking digital photographs in 2010-2014, video of the flight was also recorded in 2010 and is available on a dvd.

Wild rice was identified in both the Sand River and Pike River during the aerial surveys. Viewed from the air, two stretches of the system have been identified to contain wild rice:

- Sand River / Pike River – Sand River from just downstream of County Road 303 crossing to confluence with Pike River, Pike River to County Road 792
- Pike River – from just upstream of County Road 367 crossing to Pike River Flowage

Some areas of wild rice may have been missed when viewed from the air. Please see Figure 20 for a map outlining areas containing wild rice.

Depending on the year, rice stands in portions of the rivers varied from sparse coverage to some areas with fair to good density. In 2016, limited observations from the ground indicated sparse wild rice stands in the Sand River upstream of the Highway 169 crossing, and fair wild rice stands along the banks in the Pike River at the County Road 26 crossing. With no helicopter flight in 2016, a report for other parts of the system is unavailable.

Wild Rice Restoration

Under a permit requirement from the U.S. Army Corps of Engineers, U.S. Steel Minntac developed a Twin Lakes Wild Rice Restoration Opportunities Plan in 2013. The plan outlines activities to evaluate and potentially implement wild rice restoration in Sandy and Little Sandy lakes. Annual reports are available that summarize project activities completed by U.S. Steel Minntac since 2013.

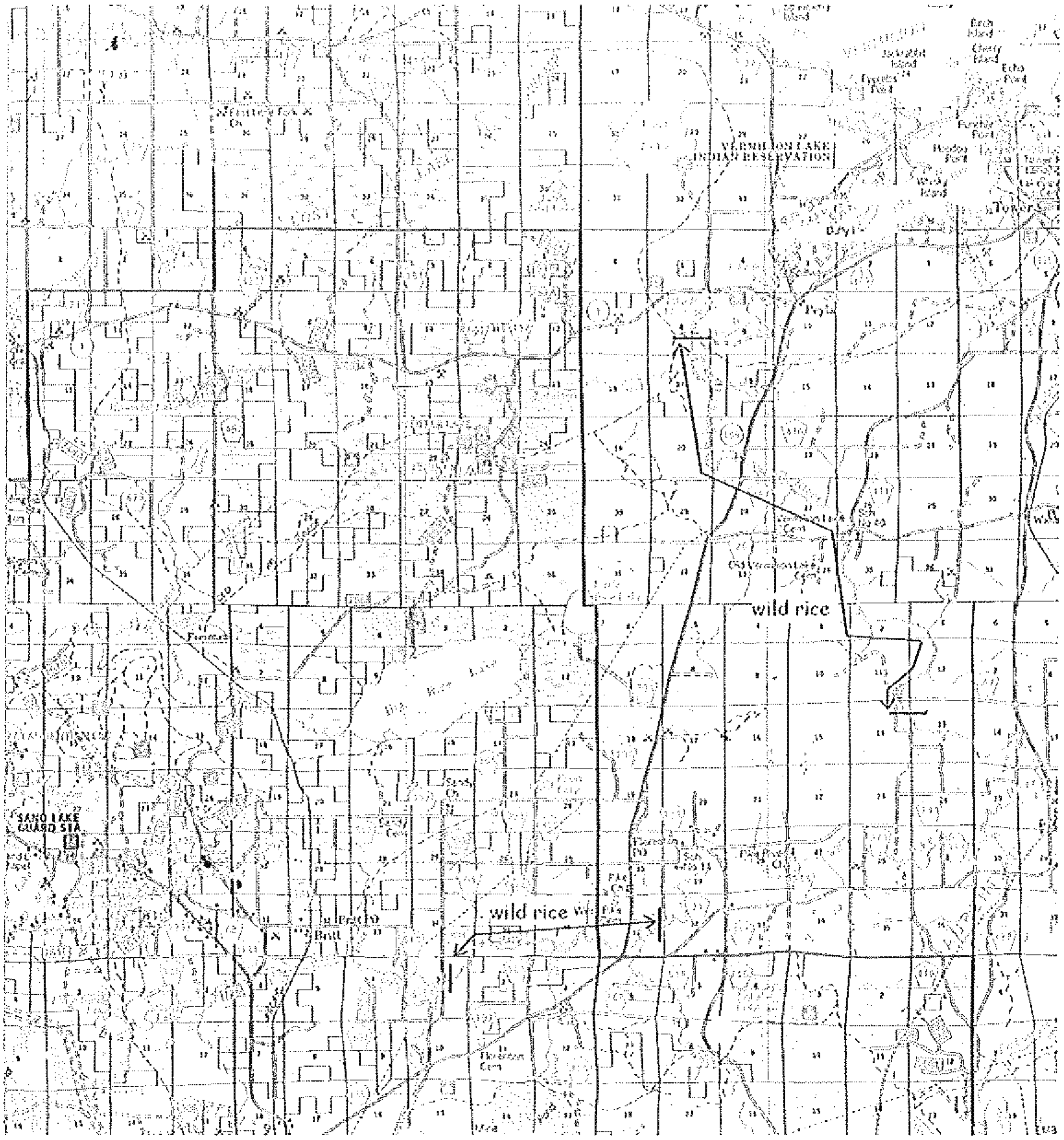

Figure 20: Wild Rice Locations in the Sand River and Pike River
(aerial surveys 9/9/2010, 9/6/2011, 9/11/2012, 9/6/2013, 9/6/2014)
United States Department of Agriculture, U.S. Forest Service, Superior National Forest map, 2003

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In 2016, staff from the 1854 Treaty Authority (Nick Bogyo, Allison Herreid, Tyler Kaspar, Jaime McDermid, Tansey Smith) assisted with field activities and data entry and analysis.